

[54] **METHODS FOR INHIBITION OF SCALE IN HIGH BRINE ENVIRONMENTS**

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[73] **Assignee:** **Petrolite Corporation**, St. Louis, Mo.

[21] **Appl. No.:** **368,699**

[22] **Filed:** **Jun. 15, 1989**

Related U.S. Application Data

[62] Division of Ser. No. 266,449, Nov. 2, 1988, abandoned.

[51] **Int. Cl.⁵** **C02F 5/14**

[52] **U.S. Cl.** **210/700; 166/244.1; 252/180**

[58] **Field of Search** **210/699, 700; 252/180, 252/181; 260/502.5 E, 501.12; 166/244.1**

[56] **References Cited**

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| | | | |
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| 4,187,245 | 2/1980 | Redmore et al. | 260/502.5 E |
| 4,234,511 | 11/1980 | Buckman | 260/502.5 E |
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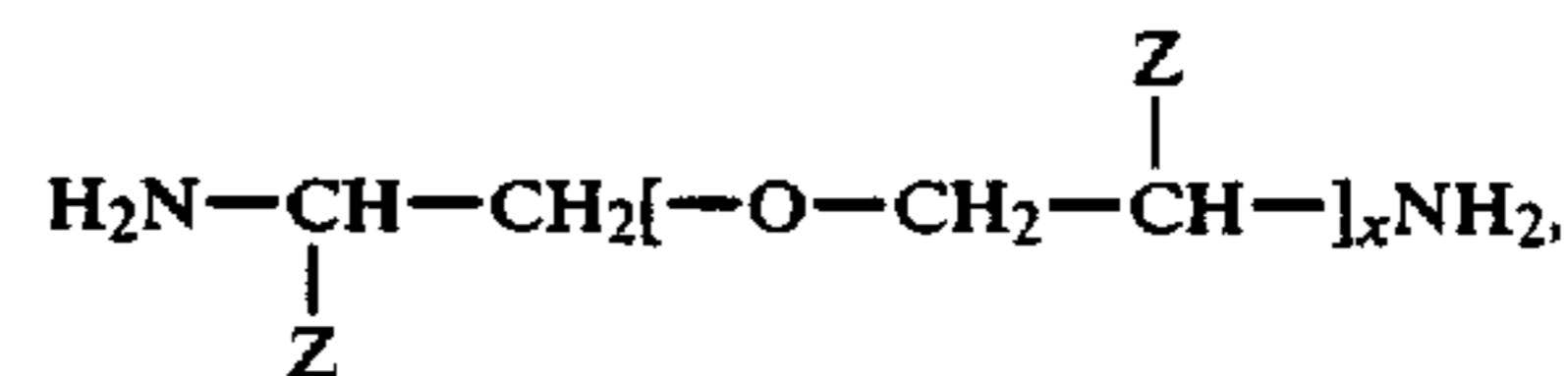
FOREIGN PATENT DOCUMENTS

213865 9/1970 U.S.S.R. 260/502.5 E

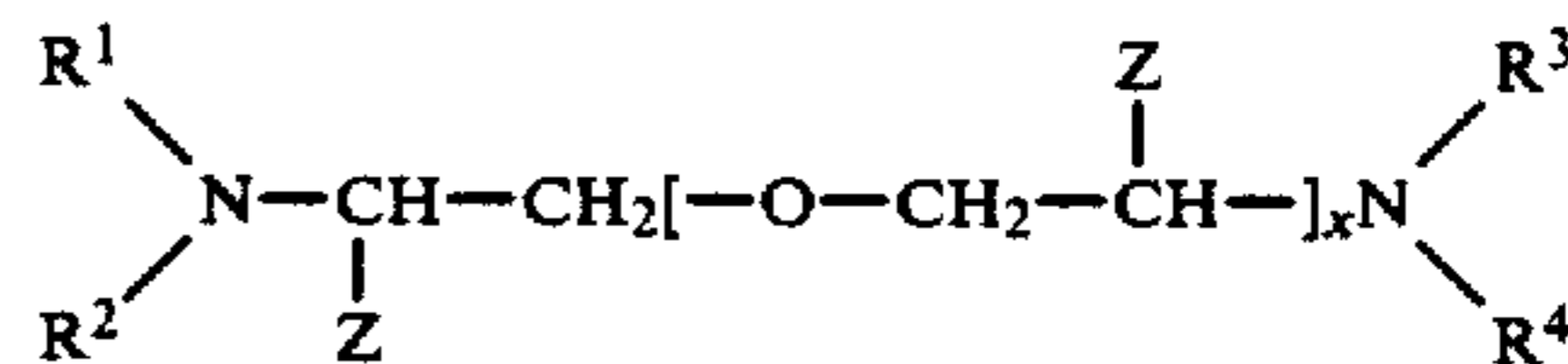
Primary Examiner—Peter Hruskoci
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[57] **ABSTRACT**

A method for preparation of an aminomethylene phosphonate useful as a scale inhibitor in high brine environments. The method comprises phosphonomethylating an amine of the formula



wherein x is an integer from 1 to 6 and the Z's are selected from the group consisting of hydrogen and —CH₃, to produce an aminomethylene phosphonate of the formula



wherein x and the Z's are defined as above and R¹, R², R³ and R⁴ are independently selected from the group consisting of hydrogen and —CH₂PO₃H₂, such that at least about 80% of the R¹, R², R³ and R⁴ in a mixture of the aminomethylene phosphonate is —CH₂PO₃H₂. Related methods and compositions are also disclosed.

2 Claims, No Drawings

METHODS FOR INHIBITION OF SCALE IN HIGH BRINE ENVIRONMENTS

This application is a divisional of application Ser. No. 266,449, filed 1988 November 02, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to compositions and methods for inhibiting oil field scale formation, and more particularly to compositions and methods for inhibiting scale formation in high brine environments.

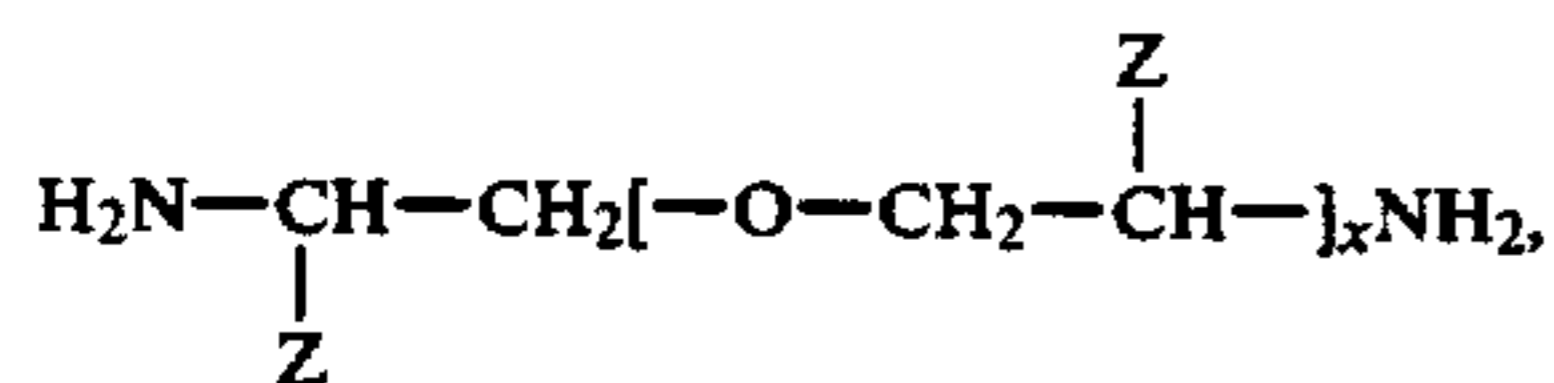
2. Prior Art

A common problem encountered in industrial activities and activities involving transport of water or transport of aqueous mixtures is the formation of scale on equipment, particularly on the inside surfaces of conduits. Oil field brines, and most commercial water contain a variety of alkaline earth metal cations, such as calcium, barium and strontium, as well as a variety of anions such as bicarbonate, carbonate, sulfate, phosphate and silicate. When such ions are present in sufficient concentrations, they tend to combine to form precipitates. Scale, formed by the deposition of any of several types of such precipitates, including calcium carbonate, calcium sulfate and barium sulfate (barite), therefore tends to coat surfaces in contact with water. Buildup of such scale on, for example, the inside surfaces of conduits not only obstructs fluid flow, but also interferes with heat transfer across the surfaces, facilitates corrosion of the surfaces and harbors the growth of bacteria.

Conventionally, scale formation is inhibited by introducing a scale inhibiting composition to the aqueous environment. Various scale inhibiting compositions have been employed to inhibit scale formation, and several such compositions are illustrated in U.S. Pat. No. 4,187,245 to Redmore et al., U.S. Pat. No. 4,234,511 to Backman, and U.S. Pat. Nos. 4,051,110 and 4,080,375 to Quinlan. Scale inhibiting compositions, such as those disclosed in the above-noted patents, have been found useful for inhibiting scale formation in many typical environments. However, they generally have limited solubility in high brine environments, that is, in brines having in excess of about 150 grams of total dissolved solids per liter of brine. Thus, conventional scale inhibitors generally have been found to be substantially less effective in high brine environments, such as those found in certain oil fields in the Rocky Mountains of the United States.

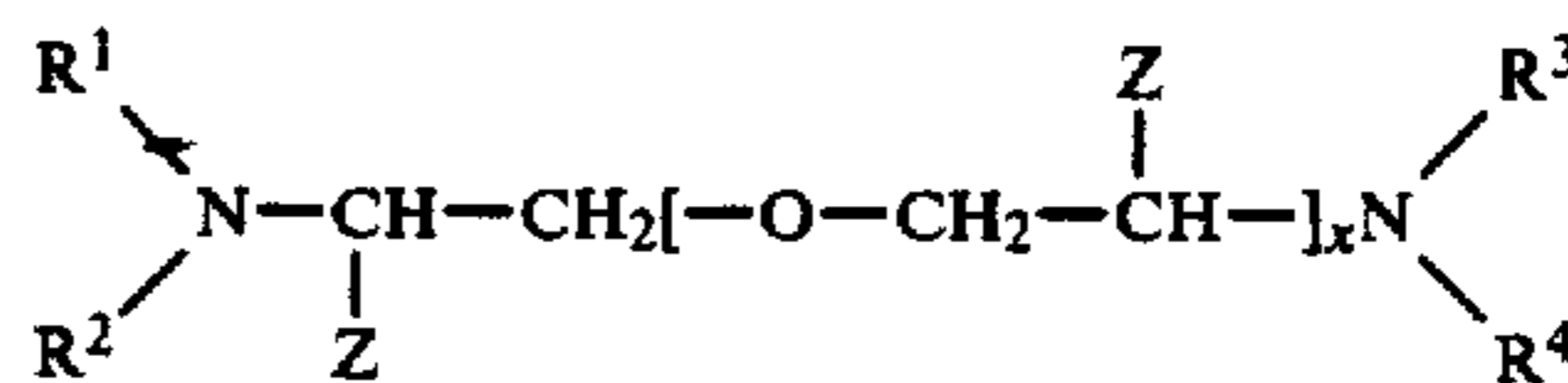
SUMMARY OF THE INVENTION

Briefly, therefore, the present invention is directed to a novel method for preparation of an aminomethylene phosphonate useful as a scale inhibitor in high brine. The method comprises phosphonomethylating an amine of the formula



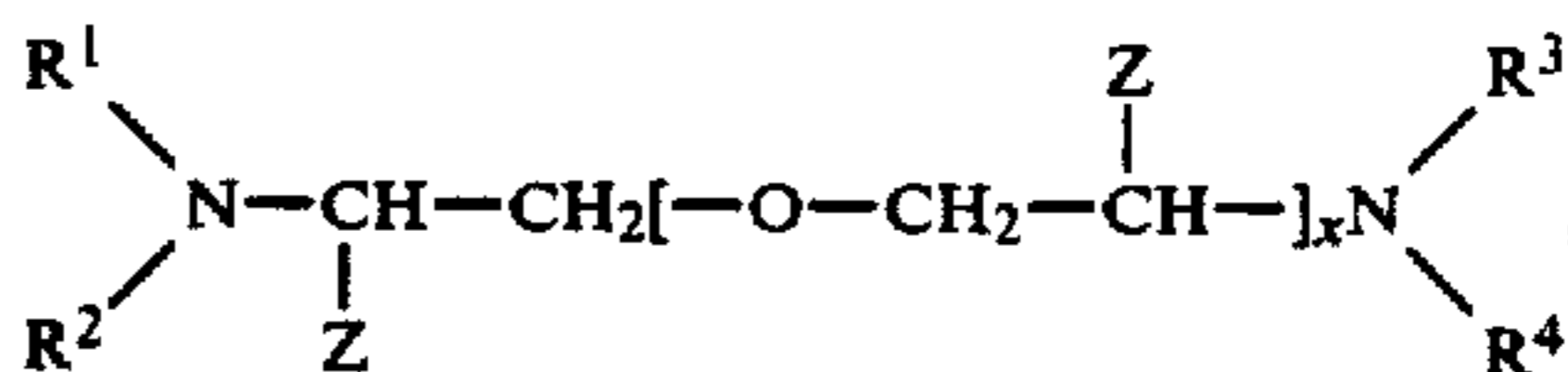
wherein x is an integer from 1 to 6 and the Z 's are independently selected from among hydrogen and $-\text{CH}_3$,

to produce an aminomethylene phosphonate of the formula



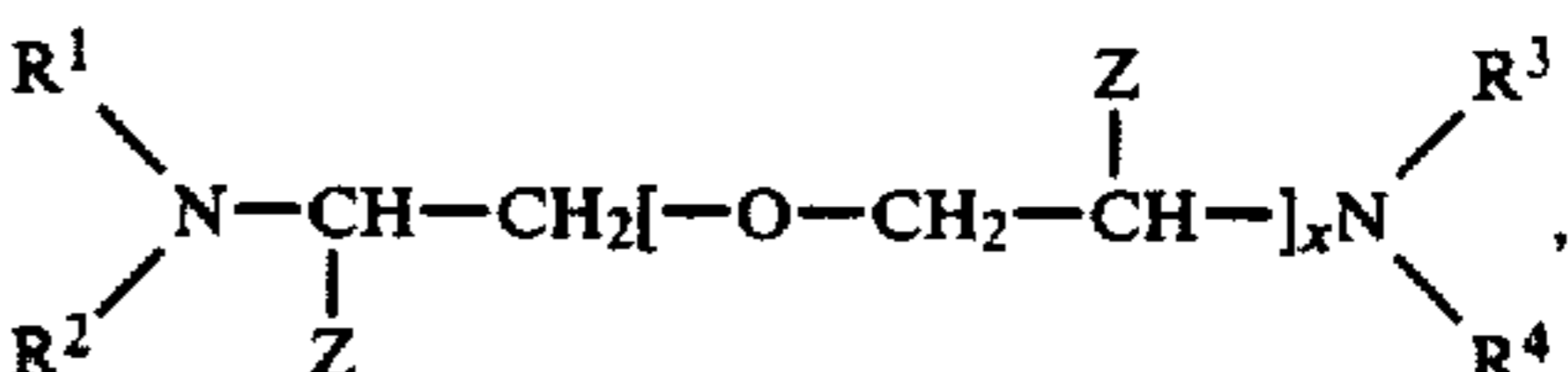
wherein x and the Z 's are defined as above and R^1 , R^2 , R^3 and R^4 are independently selected from among hydrogen and $-\text{CH}_2\text{PO}_3\text{H}_2$, such that at least about 80% of the R^1 , R^2 , R^3 and R^4 in a mixture of the aminomethylene phosphonate is $-\text{CH}_2\text{PO}_3\text{H}_2$.

The present invention is also directed to an aminomethylene phosphonate of the formula



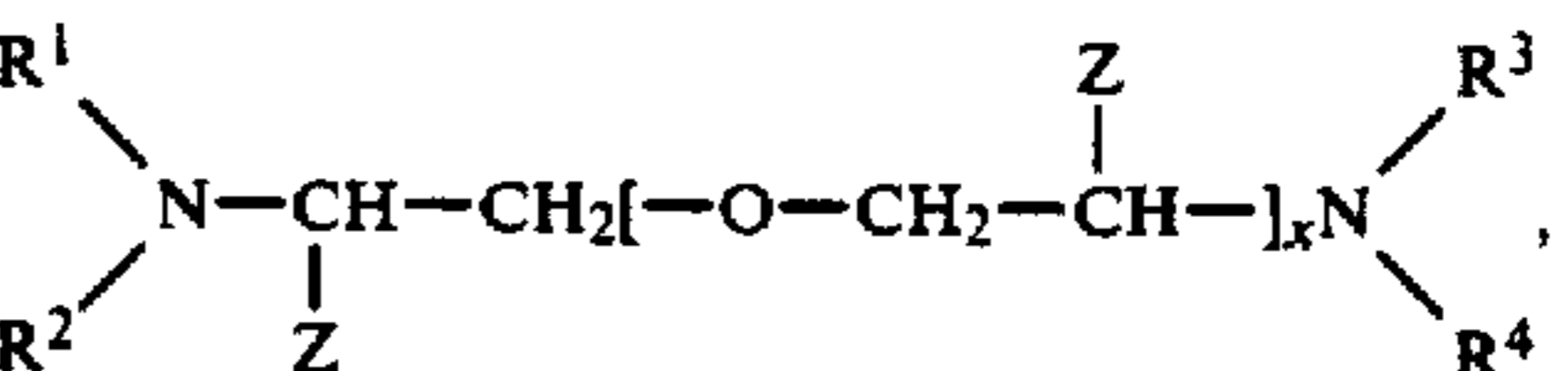
wherein x is an integer from 1 to 6, the Z 's are independently selected from among hydrogen and $-\text{CH}_3$, and R^1 , R^2 , R^3 and R^4 are independently selected from among hydrogen and $-\text{CH}_2\text{PO}_3\text{M}_2$ wherein the M 's are independently selected from among hydrogen and cations associated with Lewis bases, such that at least about 80% of the R^1 , R^2 , R^3 and R^4 in a mixture of the aminomethylene phosphonate is $-\text{CH}_2\text{PO}_3\text{M}_2$.

The present invention is further directed to a scale inhibitor composition comprising an aminomethylene phosphonate of the formula



wherein x is an integer from 1 to 6, the Z 's are independently selected from among hydrogen and $-\text{CH}_3$, and R^1 , R^2 , R^3 and R^4 are independently selected from among hydrogen and $-\text{CH}_2\text{PO}_3\text{M}_2$ wherein the M 's are independently selected from among hydrogen and cations associated with Lewis bases, such that at least about 80% of the R^1 , R^2 , R^3 and R^4 in the composition is $-\text{CH}_2\text{PO}_3\text{M}_2$.

The present invention is further directed to a method for inhibiting scale formation in a high brine environment. The method comprises introducing an effective amount of a scale inhibiting composition to a high brine environment susceptible to scale formation, said environment having at least about 150 g/l dissolved solids. The scale inhibiting composition comprises an aminomethylene phosphonate of the formula



wherein x is an integer from 1 to 6, the Z 's are independently selected from among hydrogen and $-\text{CH}_3$, and R^1 , R^2 , R^3 and R^4 are independently selected from among hydrogen and $-\text{CH}_2\text{PO}_3\text{M}$ wherein the M 's are independently selected from among hydrogen and cations associated with Lewis bases, such that at least about

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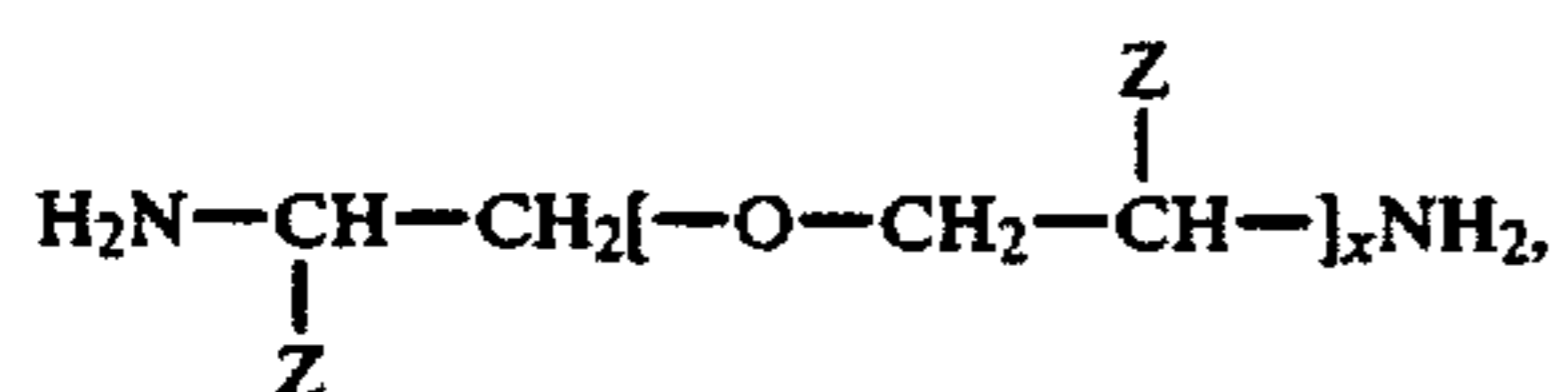
80% of the R¹, R², R³ and R⁴ in the composition is —CH₂PO₃M₂.

Among the several advantages found to be achieved by the present invention, therefore, may be noted the provision of a method for inhibiting scale formation in high brine environments and the provision of compositions useful in such methods.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with this invention, certain novel aminomethylene phosphonates have been discovered which are useful for inhibiting scale formation in a high brine environment. In particular, in contrast to conventional scale inhibitors, such compositions have been found to be soluble enough in high brines, and to maintain enough inhibitive activity in such brines, to be effective in inhibiting scale formation in high brines.

The aminomethylene phosphonates of this invention may be prepared by phosphonomethylation of an amine of the formula



wherein x is an integer from 1 to 6 and the Z's are independently selected from among hydrogen and —CH₃. It has been found that if x is too low, for example, 0, the resulting aminomethylene phosphonate is not sufficiently soluble in the high brine environments to be sufficiently effective. On the other hand, if x is too high, such as 7 or higher, the aminomethylene phosphonate prepared from the amine does not adequately inhibit scale formation. In view of these constraints, it has been found that optimally, x should be 2 or 3. Preferably, both Z's are —CH₃.

The amine is added either in pure form or, if desired, as an aqueous solution, batchwise to a mixture of phosphorous acid and a second acid in a continuously stirred tank reactor, and the reaction mixture is heated to reflux, about 100° C. to about 120° C. However, because this addition step is exothermic, cooling may actually be necessary. For nearly complete phosphonomethylation, that is, phosphonomethylation in excess of about 80%, at least about 3.2 to about 4 moles of phosphorous acid per mole amine should be employed and enough of the second acid to maintain acidic conditions in the reaction mixture.

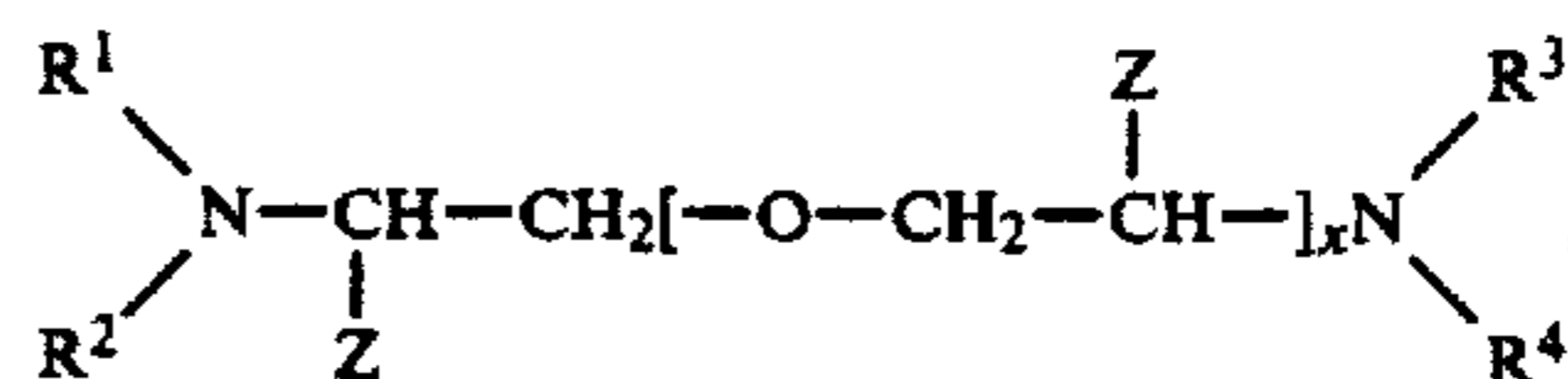
In order to maintain the acidity, the second acid should be a strong mineral acid, such as hydrochloric acid, and enough should be present in the mixture to neutralize the amine. Thus, if the second acid is hydrochloric acid, at least two moles of the hydrochloric acid per mole of amine should be employed, and preferably about three to about four moles of the hydrochloric acid per mole of amine should be employed. If water is present in the system, a greater proportion of the second acid should be used.

Formaldehyde (typically in a commercial solution such as formalin, a 37% by weight aqueous formaldehyde solution) in a molar amount at least about equal to the molar amount of the phosphorous acid, and preferably slightly greater, is added slowly to the reaction mixture. The temperature of the mixture is then maintained for about two to about four hours.

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If the reaction mixture is refluxed at about 120° C., the system should be closed and heat added to maintain the temperature. Although such measures are not necessary if the reaction is conducted at 100° C., operation of the reaction at 100° C. results in greater formaldehyde residue and a lower reaction rate.

The amine therefore undergoes a nearly 100% conversion to aminomethylene phosphonate such that the product comprises aminomethylene phosphonate of the formula



wherein x is an integer from 1 to 6 and the Z's are independently selected from among hydrogen and —CH₃, as determined by the amine precursor and R¹, R², R³ and R⁴ are independently selected from among hydrogen and —CH₂PO₃H₂. As a result of the nearly 100% conversion, at least about 80% of the R¹, R², R³ and R⁴ in the reaction product mixture of the aminomethylene phosphonate is —CH₂PO₃H₂. As discussed above, it is preferred that x be 2 or 3. It is also desired that as high a degree of phosphonomethylation as practical be achieved, and so it is preferred that at least about 90%, and optimally about 100% of the R¹, R², R³ and R⁴ in the reaction product mixture of the aminomethylene phosphonate is —CH₂PO₃H₂.

The reaction product may then be employed as a scale inhibitor. However, other additives as known in the art may be included to provide other benefits. For example, a freezing point depressant such as methanol, ethylene glycol or isopropanol may first be added to the product to avoid freezing of the inhibitor before contact with warm underground fluids. Typically, the scale inhibitor is diluted with water before use. The expanded solution thereby produced comprises from about 20% by weight to about 50% by weight of the aminomethylene phosphonate.

Alternatively, before use as a scale inhibitor, the reaction product may first be neutralized to some extent. Any Lewis base, such as an alkali metal hydroxide (e.g., NaOH or KOH), ammonium hydroxide, an amine or an oxyalkylated amine (e.g., ethanolamine), may be added to achieve the neutralization. Because the Lewis base is added merely to neutralize the product, a wide variety of bases is feasible, although, bases providing barium or calcium anions are undesirable in view of the proposed goal of scale inhibition.

Thus, if the reaction product is neutralized, the inhibitor would comprise a salt of the aminomethylated phosphonate wherein R¹, R², R³ and R⁴ are independently selected from hydrogen and —CH₂PO₃M₂ wherein each M is independently selected from among hydrogen as a result of incomplete neutralization) and the cation associated with the Lewis base (for example, the sodium ion from sodium hydroxide). Accordingly, for example, M would be independently selected from among hydrogen, alkali metals, alkyl ammonium groups (especially of from about 1 to about 6 carbon atoms), hydroxyalkylammonium groups (especially of from about 1 to about 6 carbon atoms), and ammonium, depending on the whether neutralization has been carried out and on what Lewis base or bases have been employed for such neutralization. Thus, the salt analogs of the phos-

phonomethyl group $-\text{CH}_2\text{PO}_3\text{H}_2$ correspond to the formula $-\text{CH}_2\text{PO}_3\text{M}_2$. Most preferably, the M's are sodium, potassium, ammonium or mono-, di- or tri-ethanolamine radicals, or a mixture thereof.

As with the unneutralized inhibitor, a freezing point depressant, such as methanol, ethylene glycol or isopropanol may be added to the composition or treated composition, to avoid freezing of the composition and, typically, the scale inhibiting composition is diluted before use as a scale inhibitor. The expanded solution thereby produced comprises between about 20% by weight and about 30% by weight phosphonic acid or its salt.

In operation, for example in oil or gas fields, a scale inhibiting effective amount of the composition is injected or otherwise delivered into the reservoir to provide a concentration of phosphonic acid or salt in the mixture in the conduit of between about 1 ppm and about 100 ppm to inhibit scale formation. It has been found that the phosphonic acid or salts of this invention are sufficiently soluble and effective in very high brines, such as many of the fields found in the Rocky Mountains, to provide a useful inhibitor in such environments.

The following examples describe preferred embodiments of the invention. Other embodiments within the scope of the claims herein will be apparent to one skilled in the art from consideration of the specification or practice of the invention as disclosed herein. It is intended that the specification, together with the examples, be considered exemplary only, with the scope and spirit of the invention being indicated by the claims which follow the examples. In the examples all percentages are given on a weight basis unless otherwise indicated.

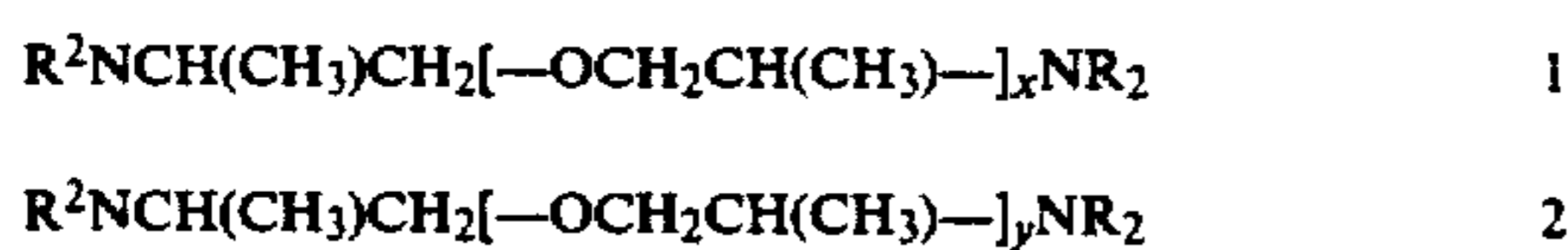
EXAMPLE 1

Jeffamine D-230 (a trade designation for an amine composition comprising a mixture of $\text{H}_2\text{NCH}(\text{CH}_3)-\text{CH}_2[-\text{O}-\text{CH}_2-\text{CH}(\text{CH}_3)-]_2\text{NH}_2$ and $\text{H}_2\text{NCH}(\text{CH}_3)-\text{CH}_2[-\text{I}-\text{CH}_2-\text{CH}(\text{CH}_3)-]_3\text{NH}_2$) (12.1 g) was added to a mixture of phosphorous acid (16.4 g), water (75 ml) and concentrated hydrochloric acid (75 ml) in a 500 ml 3-necked glass flask fitted with a reflux condenser, a magnetic stirrer, a thermometer and an additional funnel. The reaction mixture was heated to reflux (about 105°C .) and then 37% aqueous formaldehyde (16.2 g) was added dropwise over a thirty minute period. The reaction mixture was heated at reflux for an additional four hours after completion of the addition of formaldehyde. The reaction mixture was then cooled to 20° to 25°C . and stored as an acid mass. It was observed that about 95% of the NH groups were phosphonomethylated.

EXAMPLE 2

The solubility of several inhibitors was measured at three pH's in each of four types of water. A few standard commercial inhibitors and the following inhibitors were tested:

Inhibitor Structure



where R represents $-\text{CH}_2\text{PO}_3\text{H}_2$. Inhibitor 1 is a mixture of composition wherein x is 2 and of composition

wherein x is 3. Inhibitor 2 is a mixture of composition wherein y is 5 and of composition wherein y is 6.

For each test, buffer solution (1 ml) and neutralized inhibitor (0.1 ml) were added to concentrated test water (9 ml). The buffer solution for pH 5.5 was 1.0M piperazine and 1.6M HCl, for pH 7.0 was 1.0M imidazole and 0.5M HCl, and for pH 8.5 was 1.0 M "Tris" and 0.3 M HCl. The concentrated test waters were fresh water, salt water, low calcium brine and high calcium brine (in which a precipitate, presumably gypsum, formed and was filtered off before use of the brine), and contained the following salts (per liter total concentrate):

| Salt | Fresh Water | Salt Water | Low Calcium Brine | High Calcium Brine |
|---|-------------|------------|-------------------|--------------------|
| $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ | 0.055 gm. | 4.68 gm. | 4.68 gm. | 24.34 gm. |
| $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ | 0.148 gm. | 11.47 gm. | 11.47 gm. | 59.67 gm. |
| $\text{SrCl}_2 \cdot 6\text{H}_2\text{O}$ | 0.0027 gm. | 0.21 gm. | 0.21 gm. | 1.11 gm. |
| BaCl_2^* | — | 0.273 ml | 0.273 ml | 2.73 ml |
| Na_2SO_4 | 0.083 gm. | 4.14 gm. | 4.14 gm. | 1.32 gm. |
| NaCl | 10.24 gm. | 33.26 gm. | 138.5 gm. | 169.6 gm. |

* $3 \times 10^{-3}\text{M}$

The mixture was shaken and then held at room temperature for two hours. At the end of the two hours, the mixture was again shaken and an aliquot transferred to a 1 cm. cuvette. The transmittance for each test was measured with a spectrophotometer. Inhibitors 1, 2 and 4 were viscous concentrated products and so were diluted to 50% before testing. The results were as follows:

| Inhibitor | pH | (% Transmittance, 1 cm cuvette, 1% solution) | | | |
|-----------|-----|--|-------|--------------|---------------|
| | | Fresh | Salty | Low Ca Brine | High Ca Brine |
| 1 | 5.5 | 100 | 100 | 100 | 100 |
| | 7.0 | 100 | 100 | 100 | 100 |
| | 8.5 | 99 | 98 | 98 | 98 |
| 2 | 5.5 | 100 | 100 | 100 | 98 |
| | 7.0 | 100 | 100 | 99 | 99 |
| | 8.5 | 99 | 99 | 96 | 78 |
| A* | 5.5 | 100 | 99 | 99 | 99 |
| | 7.0 | 98 | 98 | 98 | 89 |
| | 8.5 | 99 | 99 | 98 | 21 |
| B* | 5.5 | 100 | 97 | 98 | 94 |
| | 7.0 | 98 | 98 | 95 | 35 |
| | 8.5 | 97 | 97 | 95 | 10 |
| C* | 5.5 | 97 | 95 | 10 | 0 |
| | 7.0 | 96 | 0 | 0 | 0 |
| | 8.5 | 98 | 0 | 0 | 0 |
| D* | 5.5 | 99 | 0 | 2 | 7 |
| | 7.0 | 99 | 2 | 10 | 4 |
| | 8.5 | 98 | 3 | 1 | 2 |

*Commercial Inhibitor

Although the absolute numbers reported for solubility may not be very significant in that, for example, a transmittance value of 98% may or may not indicate slight haziness, 95% transmittance definitely indicates haziness and heavy cloudy precipitates resulted in a transmittance of less than 1%. Extremely insoluble inhibitors sometimes produced a phase separation between the inhibitor and water, resulting in transmittance levels as high as 10% due to the difficulty in achieving adequate dispersal between the phases. Inhibitors producing less than 20% transmittance should be considered insoluble.

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 4,931,189

DATED : June 5, 1990

INVENTOR(S) : Balram Dhawan; Derek Redmore; John L. Przybylinski

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 5, lines 39-41 (Example 1):

" $H_2NCH(CH_3)-CH_2[-O-CH_2-CH(CH_3)-]_2NH_2$ and
 $H_2NCH(CH_3)-CH_2[-I-CH_2-CH(CH_3)-]_3NH_2$ "

should read

-- $H_2NCH(CH_3)-CH_2[-O-CH_2-CH(CH_3)-]_2NH_2$ and
 $H_2NCH(CH_3)-CH_2[-O-CH_2-CH(CH_3)-]_3NH_2$ --.

This certificate supersedes Certificate of Correction issued July 23, 1991.

Signed and Sealed this
Twenty-ninth Day of October, 1991

Attest:

HARRY F. MANBECK, JR.

Attesting Officer

Commissioner of Patents and Trademarks